DOT/FAA/RD-94/43

Research and Development
 Service
Washington, DC 20591

VFR Heliport Obstacle-Rich Environments: Simulation Requirements and Facilities

Brian M. Sawyer
Deborah J. Peisen
Eric H. Bolz
Systems Control Technology
Arlington VA 22209

August 1994

Letter Report

This document is available to the
public through the National
Technical Information Service,
Springfield, VA 22161

U.S. Department of Transportation

Federal Aviation Administration

1. Report No. DOT/FAA/RD-94/43	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle VFR Heliport Obstacle-Rich Environments: Simulation Requirements and Facilities		5. Report Date July 1994
		6. Performing Organization No.
7. Author (s) Brian M. Sawyer, Deborah J. Peisen, Eric H. Bolz		8. Performing Organization Report No. 91RL-150
9. Performing Organization Name and Address Systems Control Technology, Inc. 1611 North Kent Street, Suite 910 Arlington, VA 222091		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Aviation Administration Vertical Flight Program Office, ARD-30 800 Independence Avenue, S.W. Washington, D.C. 20591		13. Type Report and Period Covered Letter Report
		14. Sponsoring Agency Code ARD-30

15. Supplementary Notes

16. Abstract

This document identifies simulation requirements and facilities for the visual flight simulation evaluation of the psychological impact of an obstacle-rich VFR heliport environment on pilot performance. This report addresses the investigative process, test methodology, simulator requirements, and simulation data collection methodology.

This is the third of several letter reports that were developed as part of the preparation for evaluating pilot performance during the approach to and the departure heliports in an obstacle-rich environment. The other reports are:

(1) FAA/RD-94/41, VFR Heliport Obstacle-Rich Environments: Test and Evaluation
(2) FAA/RD-94/42, VFR Heliport Obstacle-Rich Environments: Draft Test Plan

17. Key Words Obstacle-Rich Environment, Heliport, Pilot Performance, Obstacle Hazard, Simulation	18. Distribution Statement This document is available to the U.S. Public through the National Technical Information Service, Springfield, Virginia 22161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 21	22. Price

TABLE OF CONTENTS

1.0 INTRODUCTION

This is the second in a series of two letter reports detailing the test requirements to evaluate pilot performance when helicopters are operated at heliports with a varying obstacle environment. The initial report provided test scenarios, evaluation methods, data processing techniques, and government/industry comments concerning pilot performance in an obstacle-rich environment.

This report details the issues and concerns connected with using visual flight simulation as a means of evaluating pilot performance and developing target levels of safety in an obstacle-rich environment. The report's main emphasis is directed toward assessing existing state-of-the-art helicopter simulators with regard to an individual facility's capabilities, limitations, availability, and basic user cost.

Through the use of a piloted, visual helicopter simulator, the effect of an increasingly obstacle-rich heliport environment on pilot performance will be evaluated. A body of data will be developed evaluating levels of safety within the specific flight regimes offered. Final simulation results will be verified with actual aircraft flight testing.

The overall project is divided into two phases. Phase one establishes simulation requirements and assesses facility availability. Phase two focuses on the application and analysis of phase one criteria to develop the actual simulation test. The following separate subtasks form the core of phase one:

1. test and evaluation requirements,
2. simulation requirements and facilities,
3. simulation test plan, and
4. pilot briefing materials.

After examining the results of the test requirements and facility availability, a simulation test plan will be produced as the deliverable of subtask 3. To supplement the test plan, subtask 4 provides pilot briefing materials that will explain their role and participation in the test requirements.

1.1 PURPOSE

This report will develop recommendations for simulation criteria in a piloted visual flight simulator for testing pilot performance in a VFR heliport obstacle-rich environment. Using the simulation variables defined in the initial report, "VFR Heliport Obstacle-Rich Environments Test and Evaluation," a model will be established for visual scenario development and optimal simulation requirements. This model will function as an introductory yardstick against which potential simulation facilities can be measured. In parallel with the facility assessment, an ancillary effort will provide user cost as it applies to the overall simulation phase. These cost estimates are not

useful for budgetary planning purposes until actual proposals are received.

1.2 STRUCTURE

In order to maintain a smooth transition between test specifications and facility capabilities, each requirement identified in the test plan must be carefully weighed and matched against current simulation technology. For instance, will the desired level of validation be achievable with the current state of simulation technology? Foremost, will the parameters be satisfied in order to generate an end-product that quantitatively tests the concepts of this study? In addition, availability of simulation support facilities will be provided. Comprehensive simulation modeling that will duplicate task scenarios within acceptable levels of fidelity warrants careful examination. Is there a facility that can replicate these task specifications and perform within acceptable Federal Aviation Administration (FAA) precepts?

To provide the FAA with the most cost effective assessment of simulation facilities, the information gathered from the "IFR Visual Segment Evaluation Test Plan" will be used as the nucleus of this research effort. During the development of the IFR test plan, reviews and on-site evaluations were conducted to identify suitable simulation facilities. Each project's simulator specifications, the obstacle-rich assessment, and the IFR visual segment evaluation are extremely similar in test requirements. Both projects have a visual scene condition as the common core from which the study emanates. This establishes the same basic needs for simulation:

    o   fidelity in object recognition,
    o   orientation capability and ability to align for arrival or
         departure, and
    o   vehicle flight handling qualities.

1.3 BACKGROUND

Simulations used to evaluate flight operations is in wide use throughout the aviation industry. They have graduated from the simple analog mechanical simulators of the 1930's to multi-processing digital computers with high fidelity integration. This evolution of technology offers engineers a developmental tool with refined qualities that will closely duplicate actual aircraft in any flight regime. The majority of these simulator facilities only deal with pilot training in an effort to satisfy periodic flying requirements.

True research and development (R&D) facilities are extremely limited. Most facilities are aligned to support internal development and validation of new aircraft products while keeping expenses to a minimum. Notwithstanding this, outside projects are continually solicited to balance the costs associated with simulation technology.

The advancement of rotorcraft simulation has accelerated over the past decade. Most simulation facilities have unique engineering capabilities with specialized hardware and software that maintains control of evaluation test parameters. More important, they provide a complete service including the system and skilled personnel to modify or develop the simulation to satisfy test requirements.

2.0 INVESTIGATIVE PROCESS

A matrix was established to ensure a balance between each related subject area was maintained during the research process. Using this matrix, defined test and evaluation criteria established the standards for simulation technology requirements. Facility availability and cost were introduced as ancillary factors. The investigative process involved on-site facility visits and interviews with industry to explore existing operational simulation capabilities. Analysis of the data resulted in the development of five major sections in this report:

- o facility operability survey,
- o test methodology,
- o simulator requirements,
- o data collection methodology, and
- o cost.

2.1 DOCUMENTATION

In order to match simulation requirements needed to perform this study with state-of-the-art simulators, a review and assessment was made of rotorcraft simulation technology and facilities availability. Investigative action dealt with both proficiency certification and R&D facilities and associated documentation. Key areas addressed were the type of vehicle simulated, available degree of freedom (DOF) motion, visual fidelity, and human factors engineering. A complete list of documents reviewed is annotated in the list of references.

2.2 ON-SITE FACILITY VISITS/INTERVIEWS

As part of the research for the "IFR Visual Segment Evaluation Test Plan" report, several simulation facilities were surveyed and visited. Manufacturers and training organizations operating helicopter simulators that would be capable of handling this study were solicited. The top five candidates are listed below:

- o Bell Helicopter Textron, Fort Worth, Texas;
- o NASA Ames Research Center, Moffett Field, California;
- o United Technologies Sikorsky Aircraft, Stratford, Connecticut;
- o McDonnell Douglas Helicopter Company, Mesa, Arizona; and
- o Flight Safety International, West Palm Beach, Florida.

Interviews were also conducted with the FAA National Simulator Program Staff (ASO-205) in Atlanta, Georgia; the FAA Technical Center (ACD-330) in Atlantic City, New Jersey; the FAA Rotorcraft Directorate, Policy and Procedures Branch (ASW-112) in Fort Worth, Texas (contacted at the American Helicopter Society (AHS) Annual Forum held in Phoenix, Arizona); and the FAA Field Office, NASA Ames Research Center, Moffett Field, California (contacted at the NASA/FAA Helicopter Simulation Workshop held in Santa Clara, California) to establish an appropriate course of action with regard to simulation capabilities and flight testing requirements.

2.3 FACILITY OPERABILITY SURVEY

After a preparatory review of facility capabilities, an on-site assessment was completed of the simulation candidates. It was determined that only an R&D facility could handle the required intricate software development and precise levels of visual fidelity. This narrowed the candidate list to NASA Ames and three helicopter manufacturers. A follow-up questionnaire for additional information was requested of each manufacturer. This information further defined facility availability, unique characteristics, and support availability for work that the FAA may wish to undertake as part of its ongoing R&D efforts. It was stressed that the projects currently being considered are focused on visual systems capabilities, but there is reason to believe that the horizons of the evaluation efforts could be broadened to include additional simulation studies.

It was further emphasized that the cost information requested was to enable the FAA to size its various projects for budget purposes and to provide a basis for requesting future funds. Formal cost quotes would be required with responses to the request for proposals (RFP). The following questions and statements, divided into generalized simulation areas, were directed at ensuring currency and accuracy in obtaining information on anticipated contract acquisitions. The individual candidate responses are enclosed as appendices A, B, and C.

o Operations and Computer Imagery

What type of computer-generated imagery does your system use? Is it capable of supporting daylight, dusk/night, night vision goggles (NVG) operations, other? What is the field of view of the projection system (disregarding the actual view from the particular cab in use)? Describe its operation. What is the type and capacity of the host computer?

o Types/Models of Rotorcraft

What types/models of rotorcraft can your system simulate? Does it have multiple crew station capability (single pilot, two pilots [tandem, side-by-side])? Are there a variety of performance parameters available to match each type/model simulated?

4

o   Mission Monitoring/Management Capability/Facilities

What type of mission monitoring/management capability/facilities
do you have available? Indicate whether these capabilities/
facilities are an integral part of the simulator operation and
are included in your cost estimate. If separate, please cost as
an additional available capability/service.

o   Data Collection Capability

What type of data collection capability is available? What type
of processing is available and should it be requested? It is
assumed that all analysis would be done by the FAA.

o   Visual Scenes

What types (particular locations/generic) of visual scenes are
resident with your facility? Were these provided with the
purchase of your visual system, purchased separately, or
developed in-house? Describe your in-house visual data base
development capability.

o   Moving Objects

Will your simulation accommodate moving objects in the data base
such as trains, automobiles, other aircraft, etc.? If so, how
many? Can they be controlled (put in on command), such as having
a train go by just as the aircraft is about to land?

o   Simulator - Average Loaded Cost

What is the average loaded cost per hour for the use of your
simulator? Assume a minimum of 150 hours were requested.
Indicate the number of personnel required for operation of the
simulation (included in the cost per hour estimate) and their
function. If additional personnel are required for the data
collection process, please indicate number and additional cost.
Assume that data processing and analysis will be accomplished by
the FAA. Indicate whether motion is available and is there an
additional cost for the simulator time if motion is used.

o   Data Base Development - Average Loaded Cost

What is the average loaded cost per hour for visual data base
development? Assume that a minimum of 500 hours is required.

o   Data Base Development - Site Unique

Estimate the number of hours of data base development that would
be required to reproduce the city of Indianapolis within a 6 NM
radius of the Indianapolis heliport (assume that aerial and
ground photographs will be provided), to a level of detail where

5

significant landmarks (towers, railroads, interstate highways, prominent buildings, etc.) are recognizable during day, night, and NVG conditions by a local operator.

o   Essential Equipment/Personnel

Are there any essential equipment/personnel necessary to the operation of a simulation that are not included in the above costs? If so, describe them and indicate their approximate cost.

o   Additional Simulation Capabilities/Services

Describe any additional simulation capabilities/services that are resident with your organization which may be of interest to the FAA in their R&D efforts. Indicate the approximate loaded cost of such capabilities/services.

3.0   TEST METHODOLOGY

The initial report, "VFR Heliport Obstacle-Rich Environment Test and Evaluation Requirements," developed a test methodology based on the issues described, and decided what variables needed to be included and evaluated in order to produce valid results. The test methodology is subdivided into two specific fields: 1) simulation, and 2) human factors engineering. The categorization of each of these fields provides definition and direction for testing. It is essential that all elements within each field be accurately represented and testable. This can only be accomplished through a simulation program that will effectively integrate hardware, software, engineering and professional skills. Based on the surveyed responses in section 2.3, likely simulator facility candidates have been considered.

3.1   VARIABLES AND CHARACTERISTICS

The potential number of variables and characteristics of simulation and human factors could generate a test scheme that would be too complex to produce reliable conclusions. It was decided to restrict the number of variable conditions to those most likely to be encountered, yet progressive enough to provide viable test parameters. Each category, variable, or condition as it applies to scenario development or simulation testing will require validation for a particular facility. Preliminary program evaluations of software and scenario runs will be required to ensure that all test prerequisites are satisfied prior to the actual simulation exercise. Specific simulation variables required are:

o   rotorcraft type and weight configuration,
o   various meteorological conditions,
o   different flight regimes such as takeoff, climbout, approach, and landing,
o   number and types of obstacles,

o geometric relationships of obstacles with respect to the
   heliport imaginary surfaces,
o heliport lighting,
o ambient light,
o day and night conditions,
o visual aids,
o engine failures,
o other emergency procedures, and
o single pilot cockpit configuration.

Human factors characteristics to be analyzed include, but are not
limited to:

o stress in relation to the
   o heliport environment,
   o helicopter (vehicle),
   o emergency operation situations;
o risk and uncertainty involving
   o safe/unsafe operations,
   o a combination of all factors; and
o impact of pilot experience and proficiency.

3.2 TEST PARAMETER DEFINITION

Specific test parameters as defined in the initial report must be
accurately simulated to maximize test results. Parameter definition
must be duplicated by visual scenarios and rotorcraft performance
simulation. The prime concern is ensuring that the test facility's
capabilities can adequately address task initiatives. Based on the
surveyed responses in section 2.3, likely simulator facility
candidates have now been considered. Overall facility operability
from a hardware, software, and personnel standpoint was the principal
filtering device. The resulting directive will strive to provide
results within acceptable industry standards.

4.0 SIMULATOR REQUIREMENTS

4.1 SIMULATION FEASIBILITY

State-of-the-art simulation technology has resulted in a variety of
applications for both rotary and fixed-wing aircraft. The main
consideration centers around achieving the desired fidelity for the
specific simulation initiative being evaluated. Paramount to this
issue is achieving adequately representative simulation that emulates
the required variables. Any simulation must qualify and quantify all
necessary aspects of the flight test regime. The characteristics
described in the following paragraphs are the minimum conditions a
simulation candidate must represent to verify a simulated procedure.

4.2 SIMULATION CHARACTERISTICS

4.2.1 Rotorcraft Handling Qualities and Dynamics

The difficulty in designing helicopter simulation models increases
proportionately as the complicity of components and modules
represented.

4.2.1.1 Dynamics

A single-engine helicopter model that accurately portrays actual
aircraft characteristics over the full range of flight regimes must be
used in this simulator investigation. The degree of sophistication
required of these models clearly depends upon the flight performance
characteristics to be simulated. Looking only at the VFR flight
segment allows us to refine specific simulation parameters.

4.2.1.2 Handling Qualities

To stay within the parameters of this task the qualities addressed in
the following paragraphs must be established in a simulation
rotorcraft model.

Responsiveness - The simulator must respond properly to changes
in attitude, altitude, temperature, gross weight, center of
gravity, configuration, and ground effect.

Control Forces - The control forces and degree of travel must
accurately represent the helicopter being modeled. If a generic
helicopter is modeled, the control forces must be representative
of similar helicopters in the same performance class.

Response to External Influence - The simulator must be capable of
providing representative modeling of crosswind, wind shear, and
air wake effects caused by terrain, buildings, etc.

Response Rates - The simulator must demonstrate acceptable and
consistent response rates as reflected in the cockpit
instrumentation, visual, and motion systems (if provided).

4.2.2 Visual Aids

In the heliport environment, visual aids provide course accuracy by
supplying cues to the pilot for estimating his/her position in
relation to the heliport. Visual systems are not perfect and do not
provide true position relative to the earth. For simulation, visual
aids must be representative of the operating and error characteristics
of the particular system used when executing arrival or departure
procedures from a heliport.

4.2.3 Cockpit Instrumentation

4.2.3.1 Instrument Capability

The simulator must provide sufficient instrumentation to support the execution of both arrival and departure procedures.

4.2.3.2 Navigation and Communication Equipment

The simulator must have navigation and communication capabilities that would support normal VFR operations and require normal cockpit interface. The navigation equipment must have operational and accuracy characteristics representative of the functions and performance capabilities of simulated systems.

4.2.3.3 Performance Instrumentation

The simulator must possess performance instrumentation (engine, transmission, torque, etc.) that would require normal cockpit attention.

4.2.3.4 Instrument Response

Instrument response must correlate to the rate of change and displacement of controls of the helicopter being modeled. If a generic helicopter is being modeled, the response must be typical of similar single-engine helicopters in the same performance class. Instrument response must be closely coupled to the visual system.

4.2.4 Environmental Disturbances

The simulator must be capable of emulating the ceiling and visibility conditions associated with a visual approach or departure. This must include varying weather phenomena such as variances in wind direction and velocity, precipitation, haze, and smoke.

4.2.5 Visual Scene Response

The visual reproduction must emulate the varying conditions necessary to validate the test initiatives. The parameters described in the following paragraphs are a minimum.

4.2.5.1 Visual Scene Quality

Visual scene quality and the ability to accurately depict reduced visibility are the foremost considerations for this evaluation.

4.2.5.2 Visual Scene Response Time (Transport Lag)

The visual scene must respond to abrupt pitch, roll, and yaw at the pilot's position within 100 milliseconds of the time when the helicopter would respond under the same conditions.

4.2.5.3 Resolution

The simulator must be capable of depicting a variety of obstructions with sufficient resolution (3 arc minutes or better at the pilot's eye) to support detection, identification, and avoidance capability relative to accurately presented, reduced visibility models.

4.2.5.4 Field of View

The nature of this evaluation requires a minimum field of view of 90 degrees (150 degrees preferred) horizontal and ± 20 degrees (± 40 preferred) vertical.

4.2.5.5 Day, Night, Dusk

The simulation will require evaluation during day, night, and dusk operations. Buildings and other obstacles must be capable of being properly (realistically) lighted for dusk and night operations.

4.2.5.6 Depth Perception

The simulator must provide necessary visual cues to allow assessment of sink rates and sufficient depth perception for low altitude/low airspeed maneuvering, hover, and landing.

4.2.6 Motion and Sound Cues

Motion is desirable but not required for this evaluation. If motion is available, it must conform to actual aircraft response and to external and internal inputs. It should exhibit characteristic buffet where applicable. The simulator must produce sounds corresponding in amplitude and frequency to sounds found in the represented cockpit.

4.2.7 Cockpit Viewing Angles

The pilot's viewing angles must be representative of the helicopter being modeled. If a generic helicopter is used, the viewing angles should be representative of helicopters in the same class. Unobtrusive visual shields representing cockpit structural members, glare shields, etc., may be used to block the pilot's vision where appropriate.

5.0 SIMULATION DATA COLLECTION METHODOLOGY

Potential simulation facilities must be able to perform specific data collection procedures during the simulation tests. In order to develop a set of simulator scenarios, the specific variables that are to be included must first be identified. It is not possible at this point to decide the specifics of all individual scenarios and tests. There are tradeoffs that must be made pursuant to the availability and cost of a suitable simulator, the cost of simulator visual data base development, and the scope of the evaluation to be undertaken relative

to the parameters to be tested. Therefore, an overall set of
variables to be evaluated is suggested.

5.1 SIMULATOR VARIABLES AND TEST MATRIX

This section recommends simulator variables that will be used in
developing the simulation test plan. Specific scenario design should
concentrate on the following elements:

- o visibility,
- o terrain types,
- o type heliport/helipad,
- o lighting options,
- o airspeed,
- o course orientation,
- o obstacle/structures, and
- o meteorological conditions.

By categorizing test objectives with scenario variables, issues of
perception, performance and safety can be assessed. In the test plan,
development scenarios and estimates of the number of simulator test
runs required will be evaluated against all of those variables.
Subject pilots will be teamed in small groups so that each pilot will
perform the same number of runs on a given test. Tests will be
sequenced in a randomized manner to prevent undue subject pilot
familiarity with the simulated environment (except those for which
familiarity is being specifically evaluated). One set of pilots may
be used at random for a variety of tests.

5.2 DATA COLLECTION PROCEDURES

Preparation for the data collection phase of the simulator evaluation
will involve subject pilot selection, development of pilot briefing
materials, and definition of the sequence of the tests. This section
discusses these steps, as well as the data collection methods and
parameter lists.

5.2.1 Subject Pilot Selection

Pilots selected for this study will include professional research
pilots selected from the FAA and NASA, and professional commercial and
private helicopter pilots, with emphasis on those who currently
operate in an urban environment.   The participation of current
research pilots, besides serving as an additional data source, will
help in interpreting the performance of other subject pilots, assist
with real-time evaluation of test parameters, make recommendations for
program updates, and assist with any other required/desired program
changes as data processing/analysis takes place.

5.2.2 Pre-test Briefings

Prior to conducting any tests, participating pilots will be thoroughly briefed on the objectives of the test. The specific issues and concepts being evaluated will be discussed in detail. Charts and other materials developed for purposes of the tests will be presented for review.

5.2.3 Sequencing and Performance of Test Scenarios

A plan will be developed for the random sequence of simulator scenarios to be flown by each pilot which will minimize the effect of learning on test results. This will prevent, for example, the pilot from knowing where to expect to find a specific obstacle based simply on a recently completed prior run (except for those runs whose purpose is to analyze the value of familiarity; in those cases, a specific run may be initiated to purposely allow the pilot to become very familiar with the flight simulator capabilities). Since pilot availability is always a limiting factor, entire sequences of scenarios must be presented to a given pilot in a relatively short time.

5.2.4 Logs and Parameter Lists

The data collection methods and logbook requirements will be developed prior to the tests and will be verified during the simulator shakedown tests. The recorded parameters will be stored at an appropriate sample rate (twice per second) and converted to distribution media, such as high-density diskettes or magnetic tapes, as required for post-test processing. Four sets of parameters are of interest:

- o   simulator operator log,
- o   test observer log,
- o   pilot log, and
- o   recorded parameter list.

5.3 DATA REDUCTION AND ANALYSIS

The intent of the planned task is primarily to collect, recover, and reduce simulator data to a form useful to analysts. Actual use of this data in the development or analysis of psychological effects or target levels of safety will be accomplished in phase II of this project.

The primary data reduction tasks performed as a part of this simulation will concentrate on presentation of the data in a form useful to analysts. This will involve data conversion to a presentation format showing plan and profile views overlaying a plot of the flight regime involved and its relationship to the obstacles underlying the VFR imaginary surface for each scenario. A plot of track deviation from the ideal course will be developed in the same format (plan and profile) to highlight its relationship to the actual course flown. All presentations will be annotated with time marks to

allow correlation of flight control data with the data contained in the operator and observer logs.

Other data recorded as a part of the simulator tests (including primary flight control inputs, navigation control inputs, and instrument flags and warnings) will be plotted versus time for correlation to the graphical data. Statistical analysis of pilot performance factors with regard to the plan and profile views, as well as identification of maximum deviation or deflection events, will also be performed. The results will be presented in tabular and graphical form.

6.0 BASIC USER COST

All details associated with providing simulation cost projections are estimates based on the preliminary findings in the "IFR Visual Segment Evaluation Test Plan." Both studies are similar in content with respect to their simulation requirements. The IFR report developed a test plan that detailed specific levels of effort to be performed to execute a precise simulation program. We envision that the test plan required for an obstacle-rich environment simulation will closely parallel the IFR in both time and effort.

6.1 LEVEL OF EFFORT

The calculated level of effort for the IFR report was subdivided into two main sections. This was accomplished to delineate specific areas of responsibility between the technical support and simulation contractors. Estimates for the study were designed using a "bottoms-up" approach. The test plan was subdivided into fifteen distinct subtasks.   The ground rules used in developing these costs were as follows:

- o SCT labor hour estimates were made for each subtask;
- o SCT labor hours were allotted to the required skill mix;
- o SCT labor costs were estimated using the "attachment A" MOD 002 labor rates for the period 2/ -7/ ;
- o subcontractor labor costs were estimated at $80 per hour;
- o subcontractor simulator costs were estimated at $1200 per hour. In tasks 10 and 13, subcontractor costs total $235,200, which includes: hours @ $ per hour = $192,000 and   hours @ $ per hour = $43,200; and
- o ODC includes estimated travel costs which were projected as follows: airfare - $800 per trip, lodging - $75 per night, perdiem - $32 per day, and auto rental - $50 per day.

6.2 SUMMARY OF VISUAL SEGMENT SIMULATION TASKS

A summation by the technical support and simulation contractor is presented.

Summary of Visual Segment Simulation Tasks

o   Technical Support Contractor

Estimated Resources Required

Sources	Estimated Hours
Supervisor	986
Senior Engineer	1,433
Systems Engineer	2,505
Programmer/Analyst	268
Project Management	450
Administrative Assistant	245
	5,887

Travel - As indicated by task.

o   Simulation Contractor

Estimated Resources Required - 5,671 hours as indicated by source for each task.

Travel - As indicated by task.

o   Total Estimated Cost - $ 1,398,103.

7.0 SUMMARY

The validity of using aircraft simulation in lieu of actual flight testing has been demonstrated. There are many benefits to using a simulator to analyze the VFR heliport obstacle-rich environment. Controlled test conditions allow flexibility in the test program while offering enhanced data quality and quantity. Simulation provides more precise supportive documentation which is essential to careful analysis. Each of the manufacturer's informational packages, included in the appendices, accentuates only the "positive" aspects of their simulation capabilities. No shortfalls or comparisons are offered against other facilities. Their capabilities surpass our needs and each facility's potential satisfies the simulation requirements as defined in this report. From a cost benefit viewpoint, simulation provides the best return on investment as long as meticulous review is performed to ensure task requirements are aligned with simulation capabilities.

The state of visual simulation technology is one that has rapidly changed in the past decade. Paramount to this simulation study is the quality of "visual scene fidelity." Of the four candidate systems, each offers comparable computer imagery generation at the required level of fidelity to emulate essential visual cues. The selected system must be able to effectively manage operational parameters when problems arise and provide alternative solutions. A decision

regarding which simulation facility to use requires a comparison of the benefits to be gained from each system, not just the biggest and least expensive.

After review of the information provided by NASA Ames and the three helicopter manufacturers, it has been concluded that current technology is available to perform this task. A four phase analysis process will be used to match task requirements to available candidate facilities:

- o define the objective,
- o evaluate candidate operability,
- o prioritize candidates, and
- o select the appropriate candidate.

Clear identification of simulation objectives must be a prime consideration. This is an effort to evaluate the VFR heliport environment with regard to testing a hypothesis that obstacles below the VFR imaginary surface affect pilot performance, perception, and safety. Associated data must be evaluated and structured to provide validation to pursue flight testing. One of the three commercial simulation facilities should be selected. Because of the competitive nature of these commercial vendors, they maintain a great degree of flexibility in contractual labor tasking and offer scheduling availability that could satisfy overall task requirements.

This report outlined seven major simulation characteristics necessary to adequately survey rotorcraft capabilities in support of this task. Each of the three commercial candidates can sustain our simulation requirements and measure these characteristics. These are the best candidates available in industry and government today.

Final selection should be based on the test plan proposal and the cost quotes provided by each company in line with a formal RFP.

LIST OF REFERENCES

1) "Certification of Normal Category Rotorcraft Advisory Circular," AC 27-1, Federal Aviation Administration, Washington, D.C., August 1985.

2) "Certification of Transport Category Rotorcraft Advisory Circular," AC 29-2A, Federal Aviation Administration, Washington, D.C., September 1987.

3) "Heliport VFR Airspace Design Based on Helicopter Performance," Draft, DOT/FAA/RD-90/4, Federal Aviation Administration, Washington, D.C., November 1990.

4) "Helicopter Physical and Performance Data," Draft, DOT/FAA/RD-90/3, Federal Aviation Administration, Washington, D.C., November 1990.

5) "Operational Survey - VFR Heliport Approaches and Departures," Draft, DOT/FA/RD-90/5, Federal Aviation Administration, Washington, D.C., November 1990.

6) "Helicopter Rejected Takeoff Airspace Requirements," Draft, DOT/FAA/RD-90/7, Federal Aviation Administration, Washington, D.C., October 1990.

7) "Helicopter Visual Approach and Departure Airspace Tests Volume I Summary," DOT/FAA/CT-TN87-40, Federal Aviation Administration, August 1988.

8) "Helicopter Visual Approach Surface High Temperature and High Altitude Test Plan," DOT/FAA/CT-TN 88/5, Federal Aviation Administration, June 1988.

9) Helicopter Flight Manuals.

10) Simulator Approval Test Guides (manufacturer supplied).

11) "Airplane Simulator Qualification Advisory Circular," Draft, AC 120/40B, Federal Aviation Administration, Washington, D.C., October 1990.

12) "Helicopter Simulation Qualification Advisory Circular," Draft, AC 120-xx, Federal Aviation Administration, Washington, D.C., October 1990.

13) Cooper, G.E. and Harper, R.P, Jr., "The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities," NASA TN D-5153, National Aeronautics and Space Administration, Washington, D.C., April 1969.

14) Hawley, Robert J., "IFR Visual Segment Evaluation Test Plan, Parts 1 & 2," Letter Reports, January 89/November 89.

15) Hawley, Robert J.; Bolz, Eric H.; and Sawyer, Brian M., "IFR Visual Segment Evaluation Test Plan," Letter Report, April 1991.

16) Pernaranda, Frank E. and Freda, M. Shannon, "Flight Simulation Facilities," NASA RP-1133, National Aeronautics and Space Administration Scientific and Technical Information Branch, Washington, D.C., 1985.